As discussed in previous posts, expertise is primary driver of innovation. Innovation and learning are inseparable. By definition, learning is acquiring the ability to do something new. And similarly, by definition, innovation is the creation and commercialization of something new and different. Learning and innovation are so closely related, they can't be separated. You can't have one without the other. Innovative organizations are learning organizations. It's that simple.

In this post I've compiled a relatively long list of brain principles that apply to memory and learning. There are many implications for these principles for individuals and teams seeking to accelerate their learning and to drive innovation. Subsequent to the brain principles, I've provided a list of suggestions for application of some of these principles.

Learning and Memory in the Brain

- Memory is created when a group of neurons that were activated in an experience are conditioned to subsequently fire together. Remembering occurs when, at a later date, the same group of neurons fire together.
- Hebb's Law, which can be stated as "neurons that fire together, wire together," provides a biological basis for learning.
- Learning can be defined as internalizing the ability to do something new. The "something new" can be as simple as being able to declare that Madison is the capital of Wisconsin or as difficult as being able to play the Vivaldi violin concerto in G major.
- To view it simply, we can consider learning and memory to be two sides of the same coin. Learning is acquiring and encoding. Memory is retrieval. Learning is conditioning a group of neurons to simultaneously fire. Memory is having them fire after the initial learning.
- Memory can be categorized in at least three ways: a) whether or not it's held consciously and can be articulated, b) the type of information stored, and c) the permanence of the memory.
- Explicit memory is that of which we're conscious and can declare. We believe that we know what we know, but in fact, we are only aware of our explicit memory.
- We also have implicit memory which is transparent to us. It's what we know without consciously knowing that we know. Implicit memory can't be articulated, but it reveals itself through unconscious bias and also through intuition. Unfortunately, not all of our biases and intuition are correct, and they can cause trouble for us.
- Our explicit memory is one of two types: episodic memory and semantic memory.
- Episodic memory is personal. It's a record of our personal experiences that have been stored. For instance, you may remember how you felt and what you wore on your first day of school. The memory is about the particular experience.
- Semantic memory is impersonal. It's a record of facts that we have stored. For instance, you may remember the address of the house you lived in when you were in first grade. The memory is not tied to a particular experience.
- Our implicit memory takes several forms. One example is kinesthetic memory, or muscle memory, e.g., knowing how to juggle or to throw a perfect spiral football pass or to ride a bike. You may be able to recall and even describe these things, but once learned, they can be done unconsciously, and most implicit memory occurs subconsciously. Implicit memory guides many of our habits and everyday behaviors.
- Memory can also be categorized by the permanence of the memory. Long-term memory endures for years or even a lifetime. If you still remember the name of your first grade teacher, you can be confident it's in long-term memory.

- Memory that isn't reinforced degrades and is lost, perhaps within minutes, but certainly over days and weeks. If you look at a class picture from first grade, it's likely you don't remember the names of all your classmates, but you did know them when you were six years old. If you had pulled out the picture and rehearsed the names periodically during your grade school years, the names would likely have been consolidated in long-term memory.
- There's an element of short-term memory that serves as a mental scratch pad and allows us to hold symbols, patterns, and data long enough for it to be manipulated. When you memorize a phone number just long enough to dial and immediately forget it, you're using working memory. If you multiply two two-digit numbers in your head, you're relying on working memory.
- Unlike long-term memory, working memory is very limited and, for most people, degrades rapidly after five or six bits (or chunks) of information. The limits of working memory is often identified as "7 plus or minus 2," a reference to findings of Princeton researcher George Miller in the 1950s.
- Neurological studies indicate that there's a strong link between working memory and the ability to focus and learn. Working memory may even be a fair proxy for intelligence. Certainly, it is one of the most important enablers of problem solving.
- Chunking is a way to greatly increase short term memory. Your brain does this naturally when you're reading – right now you're not interpreting each letter in each word. Your brain encodes each word, perhaps groups of words, as one chunk of information.
- Your ability to focus and pay close attention plays an important role in the encoding of information and enhancing memory.
- Organizing information so that it fits known and easily understood mental models also enhances encoding and memory.
- Information is also easier to encode if it's wrapped in context. Stories, for instance, can be valuable for providing context. The context is especially powerful if it's personal, if you're part of the story.
- Long-term memory is created by rehearsing – by practicing – with information that is in short-term memory. Spacing the practice is more effective at consolidating long-term memory. Cramming for a final exam might get you through the exam, but it's less likely to lead to long-term memory than if you space your study out over the full semester.
- Information is easier to remember when it's discovered and given meaning by the learner. You're likely to better learn information that you discover and organize or repurpose than information that you simply read or hear through lecture.
- There is no research to support the view that individuals have preferred learning styles and learn better with one style than another, e.g., auditory learners, tactile learners, visual learners, etc. Learning is enhanced by practicing in the same way and under the same circumstances – the same context – in which the actual performance or retrieval will occur.
- The emotional content of memories largely determines how easily information will be encoded in long-term memory. Strong emotions stick to memories and help anchor them in long-term memory.
- The first step in creating a memory (and learning) is attention to a stimulus. Attention intensifies our experience and causes neurons associated with the experience to fire repeatedly. The sensory input is routed through the thalamus which manages the flow of input to other brain regions. The prefrontal cortex has executive control of our attention and plays a key role in focusing on the stimulus.
- Within a fraction of a second of receiving a sensory input, the amygdala assigns an emotional value to it and triggers an emotional response which supports attention. Strong emotional content is associated with the stimulus and sticks with it as it is encoded in memory. Rehearsal is essential for

information to be consolidated in long-term memory, but extremely emotional events will likely be encoded in long-term memory, even without rehearsal.

- Also within a fraction of a second, stimuli are registered in various cortical areas, primarily (but not exclusively) as follows: visual stimuli in the occipital cortex, auditory stimuli in the temporal lobe, and other body stimuli mostly in the somatosensory cortex on the anterior portion (toward the front) of the parietal cortex. Parts of the frontal lobe manage the flow of information for purposes of manipulating in working memory.
- The hippocampus is most responsible for the creation of long-term memory. It processes information that outlives working memory by repeatedly firing the cluster of neurons associated with the newly forming memory. This firing strengthens the connection so that, in the future, when one neuron fires, others in the network fire as well. Over time, the hippocampus replays the neural networks representing memories (or approximations of those networks) in various cortical areas where they are consolidated in long-term memory.
- Sleep appears to be critical to the process of consolidating long-term memories and also to "selective forgetting" that aids in prioritizing the memories that are consolidated long-term.
- Retrieval of a memory occurs when a cue, some stimulus, ignites the neural pattern that was formed with the memory was created. The effect is that we experience a simulated reliving of the original experience, but the memory is only a reasonable facsimile. Obviously, we don't actually relive an experience – even when memories are very vivid, we still recognize that it occurred in the past the experience of the memory is different than the original event. Memories are only approximations of the original, and over time memories morph so that what we remember may bear little resemblance to the original, though we're unable to distinguish between the two.

Recommended

- Develop discipline in focused practice and rehearsal. Memorization and rehearsal strengthens working memory and embeds content in long-term memory from where it can be accessed at will and instantaneously. Focus, discipline, attention, rehearsal – all are building blocks for learning.
- Reflect on lessons learned and practice verbalizing those lessons by speaking and writing about them in your own words.
- Be inventive in applying mnemonics to provide cues for retrieval.
- Organize content into chunks.
- Space your study, practice, and rehearsals.
- Visualize content. Create a mental picture that combines elements to be remembered and associates them visually.
- Attend to your physical condition. Regular exercise and adequate sleep aid memory and learning to a significant degree.

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